Research Article

Clinical guiding significance of abdominal organs projection on the lateral lumbar X-ray for spinal microendoscopy punctures

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Aims: To measure the anatomical structure of lumbar spine by computed tomography (CT) scan, and explore the posterior edge of abdominal organs on the lateral lumbar X-ray in lateral puncture, in order to provide an anatomical basis for spinal microendoscopy to avoid abdominal organ injury.

Methods: A total of 50 patients with abdominal enhanced CT scan in our hospital were included. The spine from L1 to S1 were divided into 16 axial levels (containing the superior level of vertebral body, middle part of vertebral body, and inferior level of vertebral body) to make out safety zone, critical puncture point and critical angle in accordance with the anatomical position of posterior renal fascia and parietal peritoneum on the lateral lumbar X-ray.

Results: From L1 to S1, the projection of the lowest point of the posterior renal fascia and parietal peritoneum and the projection of the critical puncture point turns from the dorsal side of the posterior vertebral body to the ventral side. And the two projection points are in the same position on the middle level of L4 vertebral body, which is on the posterior margin of L4 vertebral body. The critical puncture angle is also gradually reduced, and is approximate 0° at the middle level of L4. There is no statistically significant difference between left and right side of the body.

Conclusion: The safety zone, critical puncture point and critical angle of L1-S1 were determined in accordance with the projection of the lowest point of the posterior renal fascia and parietal peritoneum, which provided an anatomical guidance for avoiding the injury of posterior renal fascia or abdominal organs during operation.

Keywords: Posterior renal fascia, Microendoscopic, Spiral CT

Introduction

With the rapid development of minimally invasive spine surgery, spinal microendoscopy in the therapy of prolapse of lumbar intervertebral disc has been improved. It has many advantages, such as lesser trauma, rapid recovery, precise curative effect and the protection of spinal stability. However, spinal microendoscopy also caused some complications, such as leakage of cerebrospinal fluid, the injury of cauda equine, the fracture and hematoma of zygopophysis and the injury of abdominal organs.[1–6] Since abdominal organ injury occurs obscurely during operation, and only shows intraoperative stomachache or postoperative intervertebral disc infection caused by needle punctured into the abdominal organ with bacteria.

Minimally invasive spine surgery technique becomes mature gradually, and its indications are increasing, thus lead to the increase of the risk of abdominal viscera injury. Hence, high requirements of the puncture point and the angles of working channels are needed. Currently, reports about how spinal microendoscopy avoids abdominal organ injury are lacked. The study aimed to measure the anatomical structure of lumbar spine and the surrounding tissues with computed tomography (CT) scan, and explore the posterior edge of abdominal organs on the lateral lumbar X-ray in lateral puncture, in order to provide an anatomical basis for spinal microendoscopy to avoid abdominal organ injury.

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Material and methods

Patients

From January 2014 to June 2014, 50 patients including 26 males and 24 females under abdominal enhanced CT scan in Beijing Chaoyang Hospital were collected. They were aged from 26 to 47 years with an average age of 37.06 years. Inclusion criteria are that posterior renal fascia and parietal peritoneum under abdominal enhanced CT scan displayed clearly. Exclusion criteria are as follows: (1) spine malformation; (2) previous operation history; (3) abdominal space occupying lesion; (4) ascites; (5) obvious thin or obese: body mass index (BMI) < 18.5 or BM1 ≥ 28.

CT technique

CT scan was performed using GE 64 row spiral CT scanner. The scan parameters were as follows: tube current of 250–300 mA, tube voltage of 120 kV, the screw pitch of 1–1.5, slice thickness of 5.0 mm, the reconstruction slice thickness of 1.25 mm. The entire abdomen was scanned. The contrast agent (100 mL Ultravist, 300 mgI/mL) was injected into forearm veins with an injection rate of 3.0 mL/s using high pressure injector.

Measuring method

L1 to S1 vertebral bodies were divided into 16 axial levels, including the superior level of vertebral body (superior endplate), middle part of vertebral body, and inferior level of vertebral body (inferior endplates) (Fig. 1). Then, we respectively measured vertebral sagittal diameter (L) in every level, and established *Y*-axis by the extension of vertebral sagittal diameter and established *X*-axis through the midpoint of the posterior of vertebral body which was set to be point 0. *Y*-axis direction is from the dorsal side to the ventral side, and *X*-axis is from the left side to right side. The tangent point of the parallel line of *X*-axis and posterior renal fascia and posterior parietal peritoneum was set as point D, and the left and right points were named as D1 and D2. The projections of D1 and D2 in *y*-axis were named as D1′ and D2′. The distance between point D1′, D2′ and point 0 was called OD1′ and OD2′. Critical puncture point was set as point C (Tangent line was made by the curve formed through 0 point towards the posterior renal fascia and posterior parietal peritoneum. The intersection of tangent and skin is point C.) The right and left position of C were named as C1 and C2. The projection of point C on *Y*-axis was named as C′ (the right and left position of C′ were as named C1′ and C2′). The distance between point C1′, C2′ and point 0 were named as OC1′ and OC2′. The critical puncture angle (α, the right and left angle of α were named as α1 and α2) was the crossing angle of OC and *X*-axis. The ratio of OD' and L, and OC′ and L were measured (Fig. 2).

Statistical analysis

All data were statistically analyzed by SPSS 17.0 (SPSS Inc., Chicago, IL, USA) and presented as the mean ± SD. The comparison between the left and right side data was analyzed by Student's *t*-test, and P value less than 0.05 was considered statistically significant.

Results

The measurement of the puncture projection point

The data of anterior and posterior diameter of vertebral body, the lowest projection point of posterior renal fascia and parietal peritoneum, and the critical puncture point were shown in Table 1, and the ratio of their

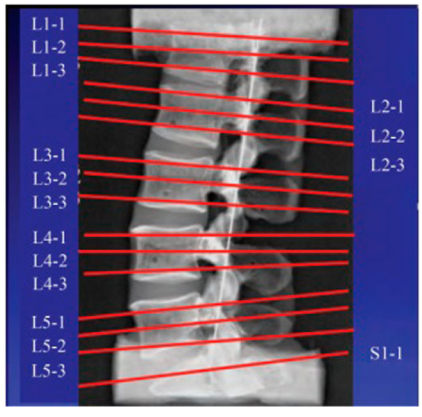

Figure 1 The level of measurement. Measure plane L1 to S1 16 axial levels, including the superior level of vertebral body (superior endplate), middle part of vertebral body, and inferior level of vertebral body (inferior endplates).

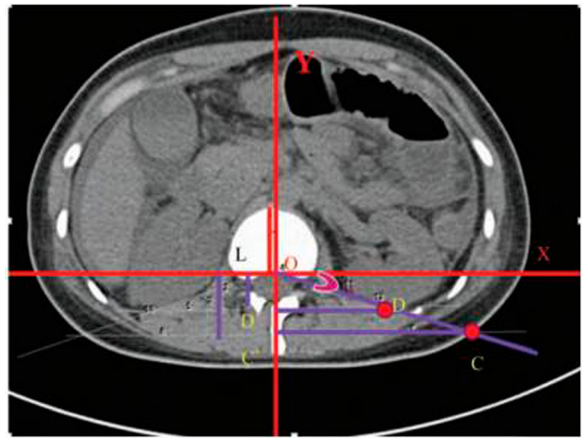

Figure 2 The graphic of CT cross section measurement. Vertebral sagittal diameter (L); The lowest point of the posterior renal fascia (OD′); critical point projection (OC′); critical angle (α); CT: computed tomography.

Table 1 Measurement results of the lowest projection point of posterior renal fascia and parietal peritoneum and the critical puncture point.

Vertebral body	Anterior and posterior diameter of vertebral body/mm		The distance of the lowest projection point of the posterior renal fascia and parietal peritoneum/mm		The distance of the critical puncture point/mm	
	Right	Left	Right	Left	Right	Left
L1-1	32. 6	32.4	−22.8	−21.8	−40.7	−38.2
L1-2	31.2	31.1	−23.8	−22.1	−41.5	−38.7
L1-3	33.9	33.7	−21.8	−21.3	−37.5	−37.1
L2-1	34.0	34.0	−21.1	−21.3	−37.3	−36.8
L2-2	32.8	32.6	−21.7	−20.9	−37.8	−36.3
L2-3	35.4	35.3	−18.4	−17.6	−32.9	−32.9
L3-1	36.1	35.6	−14.9	−15.4	−28.0	−27.9
L3-2	34.3	34.2	−16.5	−11.1	−24.6	−20.5
L3-3	34.9	35.2	−7.1	−6.7	−13.6	−13.9
L4-1	36.6	36.7	−0.6	−1.8	−2.4	−3.8
L4-2	34.4	34.3	3.7	3.2	6.6	4.9
L4-3	34.6	34.5	9.6	9.7	16.8	17.0
L5-1	36.3	36.5	15.8	15.4	27.1	26.2
L5-2	35.0	35.0	21.1	20.6	35.8	34.5
L5-3	34.4	34.2	26.2	26.4	43.8	44.0
S1-1	35.7	35.5	31.7	32.3	52.6	52.0

measurements was shown in Table 2. The results of statistical analysis indicated that there were no significant difference in the critical puncture angle between each side of the body and the ratio of their measurements.

The change of puncture point position in the different vertebral level

The location of the projection of the lowest point of the posterior renal fascia on the lateral lumbar X-ray turns from the dorsal side of the vertebral rear margin to ventral side from L1 to S1, the projection of the lowest point of L1 superior posterior renal fascia is projected on the position distancing 0.7L to the rear side of rear margin, and the vertebral posterior margin at the middle level of L4 is close to the front of the vertebral pre-margin at S1. The location of the projection of the critical puncture point turns from the back side of the vertebral rear margin to ventral side from L1 to S1 and crosses with the projection line of posterior renal fascia at the plane of L4 middle level, the projection of L1 superior margin of the critical puncture point on the position distancing 1. 26L to the rear side of rear margin, and

Table 2 Ratio of anterior and posterior diameter of vertebral body and the projection of the lowest point of the posterior renal fascia and parietal peritoneum.

Vertebral body	The distance of the projection of the lowest point of the posterior renal fascia and parietal peritoneum/Anterior and posterior diameter of vertebral body			The distance of the critical puncture point/Anterior and posterior diameter of vertebral body		
	Right	Left	*P*	Right	Left	*P*
L1-1	−0.71	−0.68	0.351	−1.26	−1.19	0.049
L1-2	−0.77	−0.72	0.121	−1.34	−1.26	0.096
L1-3	−0.65	−0.64	0.669	−1.12	−1.11	0.903
L2-1	−0.63	−0.63	0.796	−1.11	−1.10	0.834
L2-2	−0.67	−0.65	0.511	−1.17	−1.13	0.366
L2-3	−0.52	−0.50	0.488	−0.64	−0.94	0.924
L3-1	−0.42	−0.44	0.459	−0.79	−0.80	0.830
L3-2	−0.48	−0.33	0.120	−0.72	−0.61	0.046
L3-3	−0.30	−0.20	0.003	−0.40	−0.41	0.916
L4-1	−0.02	−0.06	0.295	−0.07	−0.12	0.469
L4-2	0.11	0.09	0.646	0.20	0.14	0.446
L4-3	0.28	0.28	0.969	0.49	0.49	0.976
L5-1	0.44	0.42	0.716	0.75	0.72	0.721
L5-2	0.60	0.59	0.680	1.03	0.99	0.545
L5-3	0.76	0.77	0.733	1.28	1.29	0.848
S1-1	0.89	0.91	0.526	1.47	1.47	0.989

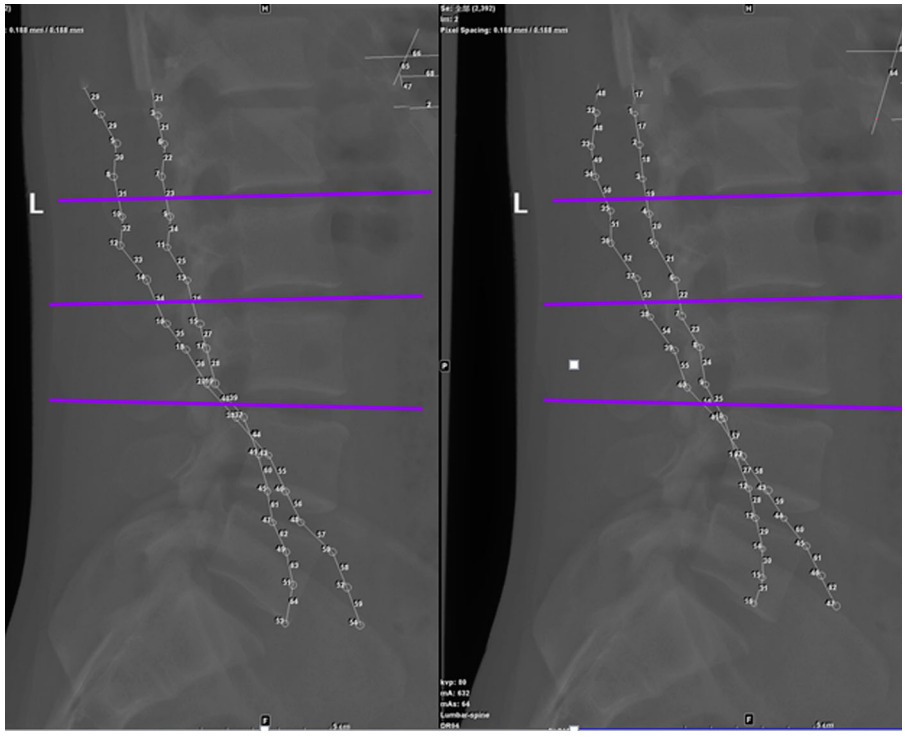

Figure 3 Continuous graph of the puncture point and the lowest point of the posterior renal fascia on the lateral lumbar X-ray. (A) continuous graph of the right side of the puncture point and the lowest point of the posterior renal fascia; (B) continuous graph of the left side of the puncture point and the lowest point of the posterior renal fascia; Line 1: refers to the puncture point of the line that is the safety line; Line 2: refers to the final point of the renal fascia connection.

the vertebral posterior margin at the middle level of L4 is close to the front of the vertebral pre-margin at S1 and in a distance of 1.5L to vertebral rear margin. The above-mentioned results only consider the safety of puncture for abdominal viscera, which should be noted. In accordance with above-mentioned measurements and ratios, we can obtain two continuous curves of the puncture point and the lowest point of the posterior renal fascia on the lateral lumbar X-ray (Fig. 3).

The data of critical angle and the distance from puncture point to puncture of posterior midline is shown in Table 3. The results of statistical analysis indicated that the distance from puncture point to puncture of posterior midline and the critical angle between each side of the body have no statistical difference. The critical angle of the puncture is 20° pointing to the dorsal side at the L1 superior margin and 0° at L4 middle level, and is 15° pointing to the inferior margin of L5. The distance from puncture point to puncture of posterior midline is 127 mm at the superior margin of L1 vertebra, and gradually enlarged from L1 superior margin to S1 superior margin, and is 281.5 mm at S1 superior margin. Compared with the present reference data of puncture (11–14 cm), the moving range of puncture point was obviously increased.

Verification on human specimen

We collected a fresh frozen human specimen (age: 37 year-old, sex: male, death causes: accidental death) without abdominal wound and with complete spinal

Table 3 The critical angle and the distance from puncture point to puncture of posterior midline.

Vertebral body	The distance from puncture point to puncture of posterior midline/mm			The critical angle/(°)		
	Right	Left	*P*	Right	Left	*P*
L1-1	18.5	126.0	0.085	−20.27	−20.69	0.530
L1-2	129.2	130.5	0.329	−19.80	−20.38	0.427
L1-3	133.9	134.2	0.815	−18.58	−19.72	0.040
L2-1	137.7	136.4	0.269	−18.52	−19.01	0.383
L2-2	144.0	143.6	0.785	−17.49	−17.79	0.567
L2-3	152.8	153.4	0.732	−15.07	−15.99	0.173
L3-1	164.9	163.0	0.347	−12.52	−13.29	0.278
L3-2	176.7	175.3	0.500	−10.53	−10.14	0.608
L3-3	187.9	189.7	0.465	−0.637	−7.01	0.383
L4-1	204.4	205.1	0.787	−1.37	−2.29	0.367
L4-2	215.0	216.2	0.686	2.18	1.59	0.565
L4-3	228.5	229.3	0.776	6.45	6.46	0.990
L5-1	240.5	241.9	0.659	10.26	9. 95	0.758
L5-2	255.2	254.2	0.744	10.74	13.45	0.732
L5-3	268.8	270.1	0.699	16.86	17.18	0.709
S1-1	281.3	281.6	0.911	20.12	20.77	0.371

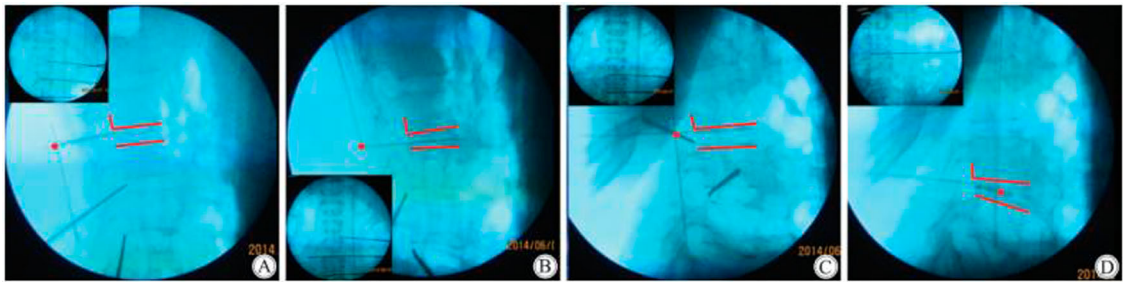

Figure 4 Kirschner needle puncture on the lateral lumbar X-ray. (A) L1-2 level; (B) L2-3 level; (C) L3-4 level; (D) L4-5 level.

structure under X-ray examination. Safety verification was performed with the puncture of Kirschner wires on L4-5, L3-4, L2-3 and L1-2 levels. Puncture was performed from puncture point to vertebral midpoint under fluoroscopic localizing of lateral lumbar vertebrae with prone position. Puncture point was in accordance with the upper limit of the safety zone obtained in this study, and that is as following: L4-5, L3-4, L2-3 and L1-2 is + 49%, –12%, –94%, –112% ("+": the direction is ahead vertebral posterior; "−": the direction is aback vertebral posterior). The exploratory laparotomy with prone position was performed after puncture. Four Kirschner wires were not in the abdominal cavity, and the kidney and posterior renal fascia were not injured (Figs. 4 and 5).

Discussion

Spinal microendoscopy is performed with local anesthesia via the puncture of posterolateral lumbar spine, and the working channel is inserted into the spinal canal or intervertebral disc through intervertebral foramen, and then the prolapsed intervertebral discs are excised with the help of endoscope.[7] The working channel should be located in the lower-back muscles on the dorsal of the vertebrae. During the process of puncture, it is a must to avoid renal injury caused by the puncture needle threaded through ventral side or abdominal organ injury induced by puncture needle penetrating posterior parietal peritoneum. Among the complications caused by microendoscopy, abdominal organ injury was rarely reported. However, with the development of spinal microendoscopy, its indications are increasing, and it has higher requirements for the puncture point and the angle of working channel. Meanwhile, for the beginners, the puncture may induce abdominal organ injury because of unfamiliar with the location of puncture point and puncture angle. Hence, the study aims to make out the safety zone, critical puncture point and critical angle according to the anatomical position of posterior renal fascia and parietal peritoneum on the lateral lumbar X-ray to provide an anatomical base to avoid abdominal viscera injury.

Based on the radiological anatomy, Meyers *et al.* reported that spatia retroperitonaeale centered on renal fascia and was divided into anterior pararenal, perirenal and posterior pararenal spaces.[8] The ureter courses the anterior pararenal space and runs down in front of psoas major. The back side of kidney is posterior renal fascia attached inward to the different position of lumbar muscular fascia, and the attached position of posterior renal fascia is more inside with the lower plane of spine. Upward, the right of posterior renal fascia blends into diaphragm inferior fascia and the left side blends into left diaphragm inferior peritoneum; downward, posterior renal fascia is attached into fossa iliaca; outward, posterior renal fascia blends into pre-renal fascia to form ipsilateral vertebral fascia.[9] The space back of peritoneum of the renal underneath is wider, and is filled with adipose tissue and without important visceral organ in it. Hence, it is safe and reliable for visceral structures (excluding

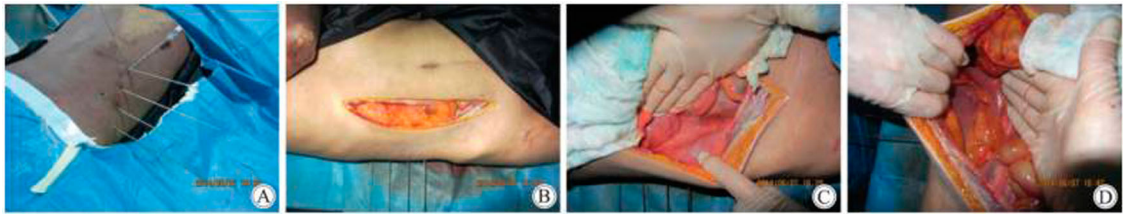

Figure 5 Exploration of the needle position. (A) Kirschner needle puncture; (B) cut the muscular layer; (C) display of peritoneum; (D) posterior renal fascia.

lumbosacral plexus due to the reaction with touching nerve of puncture needle under local anesthesia) as long as puncture needle or working channel is placed in back of posterior renal fascia or posterior parietal peritoneum.

X-ray was used to locate spinal microendoscopy, and lateral X-ray was used to locate the posterior renal fascia and parietal peritoneum based on the structures projected to sagittal axle wire. On the CT axial plane, puncture point C which is the cross point of the skin and the tangent line of the posterior renal fascia and parietal peritoneum's arc through point 0 is an idea safe point, because puncture point on the skin biasing towards the ventral side of point C will injure the kidney or break the parietal peritoneum to injure the organ. Hence, we propose a theory of safety zone, which is defined from the continuous graph of the subpoint of critical puncture point on sagittal axle wire. Puncture in the ventral side of the safety zone will injure the kidney or other organs, whereas puncture in the dorsal sides of the safety zone is safe for patients.

Lumbar disk hernia most frequently involves L4-5, followed by L5-S1, and followed by L3-4, L2-3 and L1-2. Therefore, puncture in L4-5 gets most focus. Due to the shield condition of ilium, the lateral puncture point in L5-S1 level is close or higher to L4-5 level. Moreover, it is reported that someone accomplished the surgery of lumbar disk hernia in the levels of L4-5 and L5-S1 via the same incision.[10] In terms of L5-S1 level, puncture needle placed horizontally (parallel to the *X*-axis) or puncture biasing towards the ventral side will not injure the viscera. Besides, parallel puncture is completely unnecessary in the clinical works. Hence, safety concern does not exist for the viscera. According to the measurement date, critical puncture point in L4-5 is projected onto the location distant from vertebral posterior front side for 0.5L with 6.4° of puncture angle. Critical puncture point is 22.9 cm distant from posterior median line, which is far surpass for the real request in the clinic. Hence, somebody have argued 0° of puncture angle (horizontal puncture), which has the anatomical evidence. However, horizontal puncture point is inappropriate to too skewed towards cranial, such as that puncture point located in inferior margin of L3 will cause viscera injury.

In clinic, different doctors have different choices of puncture point location based on their experience. However, theoretically ideal puncture point can be measured by CT abdomen and magnetic resonance. The ideal target point of puncture is point 0, puncture needle stick into the intervertebral foramen through ventro-superior articular process, followed by into point 0 in the central of canalis vertebralis. Hence, the tangent line of point 0 and ventral superior articular process extends outward, and the focal point of the extended line and skin is the ideal puncture point. However, in practice, CT and MR images provided from the imaging department cannot show total abdomen, they can only show limited parts around centrums. In this situation, clinical doctors cannot make use of conventional CT and MR images to obtain the ideal location of puncture point. That's why many minimal invasive experts choose the puncture point via their solid clinical experience. The ideal puncture point measured from the angle of radiography is safe in the levels of L4-5 and L5-S1, but it will injure kidney or hollow organs with the same method in L1-2 and L2-3. Thereby, the safety zone has guiding significance for clinical practice.

We note that the slopes of two curves in the level from L3 superior margin to L4 superior margin is large, which is related with the location of kidney. The lowest point of kidney locates on L3 middle-lower part and is not lower than L3 inferior margin, so horizontal puncture cannot be performed in the level of L3-4. According to our measured data, the projection of critical puncture point in L3-4 is distant from the back side of vertebral posterior for 0.41L with 6.5° of puncture angle, and critical puncture point is distant from posterior midline for 18.8 cm. However, the puncture needle may be parallel to L3 superior margin in practical clinic, so the critical puncture point in L3 margo superior should be in 0.8L back of centrums.

On the other hand, critical puncture point should be above the L2-3 intervertebral disc levels for L2-3 disc lesion. According to our measured data, the projection of critical puncture point in L2-3 is distant from the back side of vertebral posterior for 0.94L with 15.5° of puncture angle, and critical puncture point is distant from posterior midline for 15.2 cm. However, many doctors get used to choose the location of puncture point near the head. Hence, if the superior margin of L2 is chosen, critical puncture point should be in 1.1L back of vertebral body.

At present, the patient with L1-2 disc lesions treated by spinal microendoscopy is less, but still can be encountered in the clinic. According to our measured data, the projection of critical puncture point in L1-2 is distant from the dorsal side of vertebral posterior for 1.12L with 20° of puncture angle, and critical puncture point is distant from posterior midline for 13.4 cm. Similarly, many doctors get used to choose the location of puncture point near the head, so the puncture location should be based on the projection of the

practical puncture point. In order to investigate the accuracy of these data, we collected a fresh frozen human specimen. The dissected result indicated that all puncture points was safe and reliable, and would not injury to abdominal organs.

This study had some limitations. Firstly, the sample size was relatively small the sample origin was limited to a single locale and might has bias with the general population of our country. Secondly, the sex factors (male:female = 1:1) was considered in this study, but the age factors was not considered in this study. Thirdly, the patients were examined with CT scan in the supine position, and spinal microendoscopy often took prone or lateral position. Whether the prone position impacts the position of viscera needs further research. However, the patients were hanging off in the prone position in order to obtain better respiratory function. We think that the position has less influence on viscera position. Therefore, this study still has guiding significance for the clinical practice.

In conclusion, this research defines the safe zone and the definite critical puncture point and puncture angle from L1 to S1 according to the projection of the lowest point of the posterior renal fascia and parietal peritoneum. It provides an anatomical reference to avoid intra-operative injury of posterior renal fascia or abdominal organs.

Disclaimer statements

Contributors None.

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Declaration of interest None.

Conflicts of interest The authors declare that they have no conflicts of interest.

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